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The ultimate Aberdeen knot

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ABSTRACT

INTRODUCTION The Aberdeen knot has been shown to be stronger and more secure than a surgeon's knot for ending a suture line. No data exist as to the ideal configuration of the Aberdeen knot. The Royal College of Surgeons of England in their Basic Surgical Skills Course, 2002 recommended six throws. The aim of this experiment is to find the ideal combination of throws and turns.

MATERIALS AND METHODS Aberdeen knots of various configurations were tied in 0-PDS suture (Ethicon, Johnson and Johnson). Each configuration was tied 10 times. A materials testing machine was used to test the knots to destruction in a standardised manner.

RESULTS The knots were seen to behave in two ways. They either slipped and unravelled, or broke. Knots tied with fewer than three throws were unreliable. Knots tied with three throws and two turns appear to be the strongest configuration. Adding further throws and turns does not increase the strength of an Aberdeen knot.

CONCLUSIONS An Aberdeen knot tied with three throws and two turns is the ultimate Aberdeen knot.

KEYWORDS

Knot – Suture – Aberdeen knot – PDS

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The Aberdeen knot has been shown to be stronger and more secure than a surgeon's knot for ending a suture line.[1] It is a development of the highwayman's hitch[2] or the high post hitch.[3] Both of these knots are designed to be released easily as they are used for temporarily securing a horse or a boat to a post. The Aberdeen knot is designed not to be undone and, therefore, does not have an in-built mechanism to be easily untied. The Aberdeen knot became so named when Sir James Learmonth (Professor of Surgery at Aberdeen University from 1932–1938) noted that it used less thread than the contemporary surgeon's knot, and hence must have been invented by a Scot.[4]

There are no published data on the ideal configuration of the Aberdeen knot. Does adding more and more parts to the knot make it any stronger? Is there a point of diminishing returns?

The terminology for describing Aberdeen knots is unclear. For the purpose of this paper, a throw is passing a bight (loop) of the suture material through another bight as shown in Figures 1–5.

The Aberdeen knot looks complicated to tie but is actually one of the easiest and quickest of the surgical knots. It is perhaps for this reason that surgeons do not trust it, as they do not believe that such a simple knot will hold.

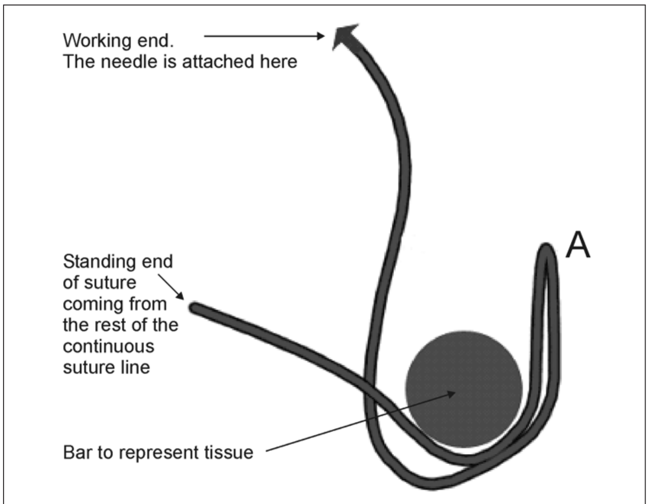

Figure 1 A loop or bight is formed in the suture (A), and passed under the bar. In surgery, the loop is taken as the last bight of the suture line.

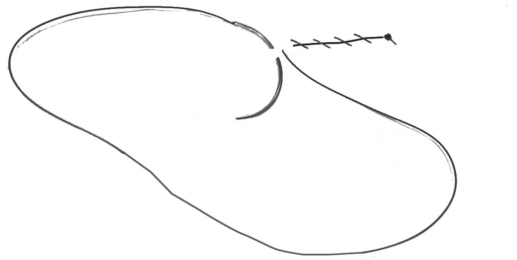

Figure 2 An image of a continuous suture line showing the formation of a loop as the last bight of the suture line.

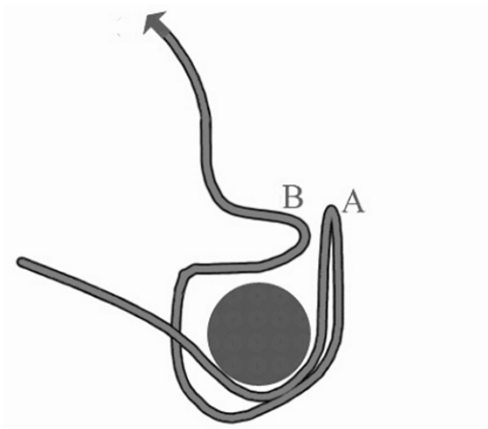

Figure 3 A further loop or bight (B), is formed in the working end and passed through the loop A.

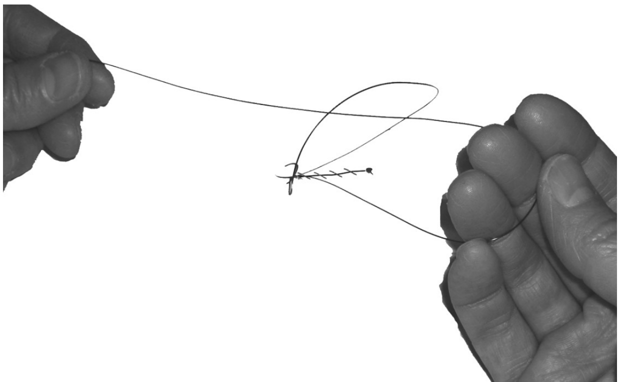

Figure 4 The second bight being passed through the first, as described in Figure 3.

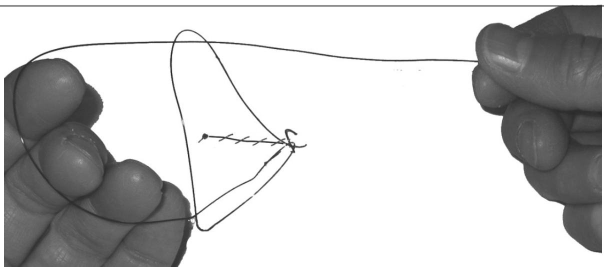

Figure 6 Another bight being passed under the newly formed loop to form 2 throws.

Figures 1–9 illustrate how to tie an Aberdeen knot to end a suture line. The bar in the line diagrams represents the tissue that the suture would encircle *in vivo*.

There is no limit to the number of throws and turns that could be incorporated into an Aberdeen knot. The Royal College of Surgeons of England in their Basic Surgical Skills Course, 2002 recommended six throws and one turn.[5] The aim of this study was to find the ideal combination of throws and turns.

Materials and Methods

A materials testing machine (Instron model 1122) was used to test the knots to destruction. The machine was calibrated, according to the manufacturer's protocol, at the beginning of each session and every 3 h thereafter. Each knot to be studied was tied in 0-PDS II (Ethicon, Johnson & Johnson) around a 10-mm bar which was fixed to the base of the Instron. The end of the suture that would normally be from the continuous line was inserted into the jaws of the Instron, 5 cm from the knot.

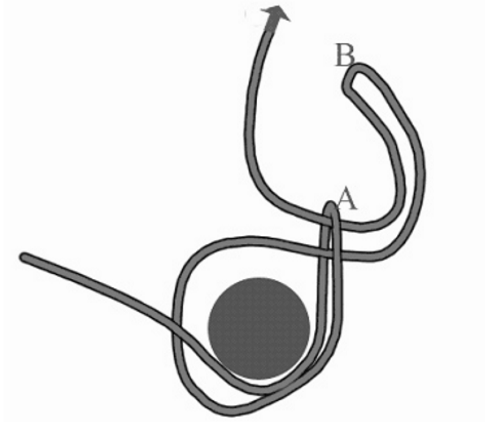

Figure 5 The bight B has been passed through A. This is called a throw. This step can be repeated any number of times to give varying numbers of throws.

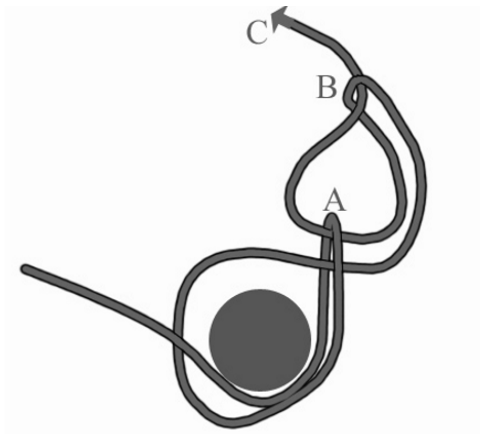

Figure 7 To finish the knot, the end of the suture, C, is then passed through the new loop formed by the previous bight, B. This is called 'one turn'.

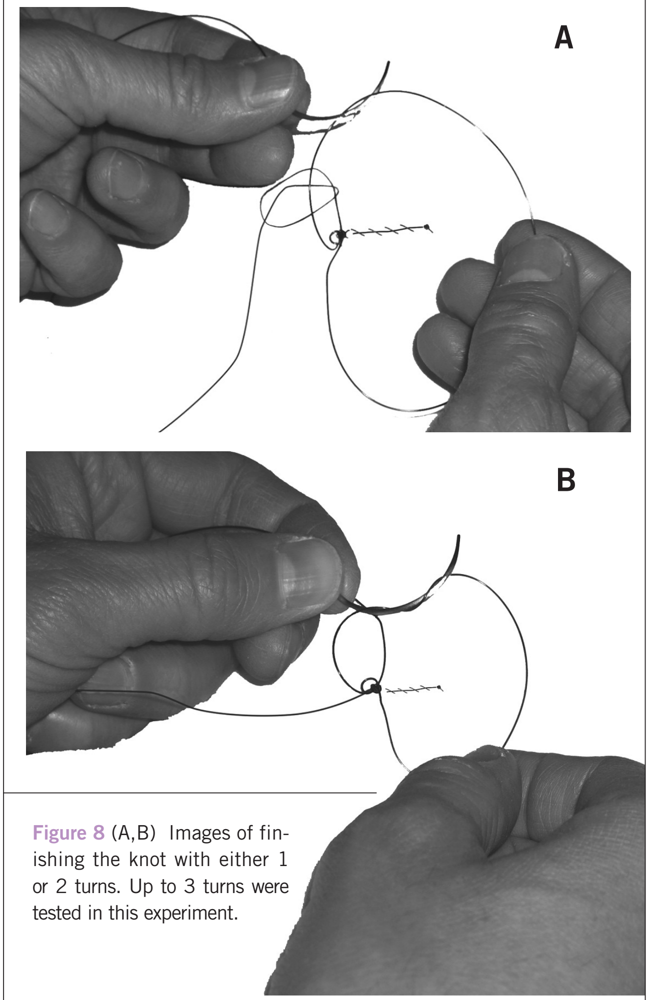

Figure 8 (A,B) Images of finishing the knot with either 1 or 2 turns. Up to 3 turns were tested in this experiment.

Each knot configuration was tested 10 times: from 2–6 throws and 1–3 turns. The crosshead speed of the Instron was 10 mm/min. The output from the Instron was recorded on its chart recorder. The Instron was calibrated in kilograms force. (To convert to the SI units of newtons, multiply kilogram force by g, the acceleration due to gravity, approximately 9.80 ms^{-2}.)

Results and Discussion

The Aberdeen knot was seen to behave in two different ways. It would either be insecure and fail by slipping or not slip but break. If it slipped, it always failed at a lower force. The Aberdeen knot did not slip when formed with fewer than three throws. The effect of adding more throws is shown in Figure 10.

Figure 10 demonstrates the effect of adding extra throws to the Aberdeen knot. The bars illustrate the average breaking force of knots with 1–3 turns. It appears that the knots made with fewer than three throws performed poorly, compared to the knots with three or more throws. The operator (PS) found that if a knot was made with more than three turns, it was more difficult to snug it down initially and such a loose knot was found to introduce significant slack into the suture line as it tightened.

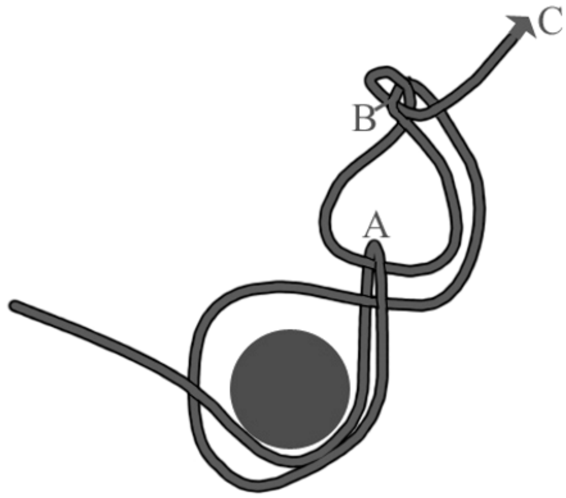

Figure 9 This final step can be repeated by passing the working end, C, under the bight B twice to give a knot configuration of one throw and two turns.

Figure 10 has perhaps oversimplified the situation, as each column relates to knots tied with different numbers of turns. Figure 11 shows the mean breaking force for each individual configuration. The actual data are summarised in Table 1.

It can be seen from Figures 12 and 13 that, due to insecurity, the knot constructs with one or two throws are not as strong as those with three or more throws.

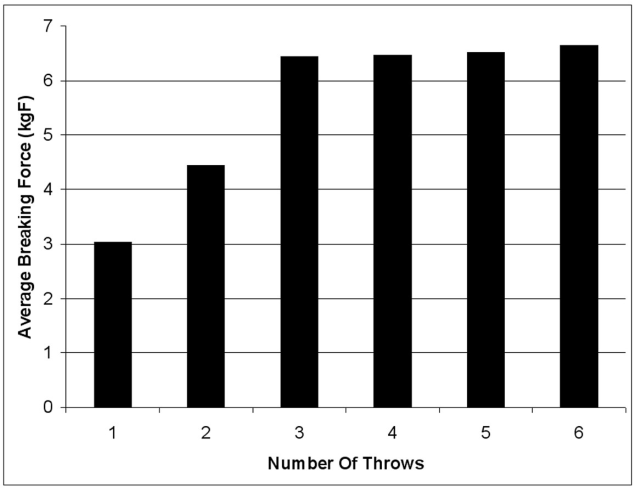

Figure 10 Bar chart of average breaking force for Aberdeen knots with number of throws specified.

Table 1 Mean breaking force (kilograms force)

	Mean	SD	Min	Max	Group
1 Throw – 1 Turn	0.73	0.30	0.3	1.3	1
1 Throw – 2 Turns	4.71	2.95	0.4	7.9	2
1 Throw – 3 Turns	3.67	1.42	1.4	6.6	2
2 Throws – 1 Turn	5.36	1.58	1.7	6.9	2
2 Throws – 2 Turns	4.04	1.63	2.4	6.9	2
2 Throws – 3 Turns	3.94	2.26	0.5	6.4	2
3 Throws – 1 Turn	6.23	0.70	5.3	7.7	3
3 Throws – 2 Turns	6.57	0.51	5.8	7.5	3
3 Throws – 3 Turns	6.51	0.74	5.4	7.8	3
4 Throws – 1 Turn	6.18	0.65	5.5	7.6	3
4 Throws – 2 Turns	6.48	1.09	5.2	8.1	3
4 Throws – 3 Turns	6.74	1.19	5.0	8.1	3
5 Throws – 1 Turn	6.37	1.04	4.8	7.6	3
5 Throws – 2 Turns	6.48	0.75	5.3	7.3	3
5 Throws – 3 Turns	6.70	0.85	5.2	7.8	3
6 Throws – 1 Turn	6.26	1.15	4.3	7.8	3
6 Throws – 2 Turns	7.22	0.79	5.7	8.0	3
6 Throws – 3 Turns	6.47	0.66	5.7	7.4	3

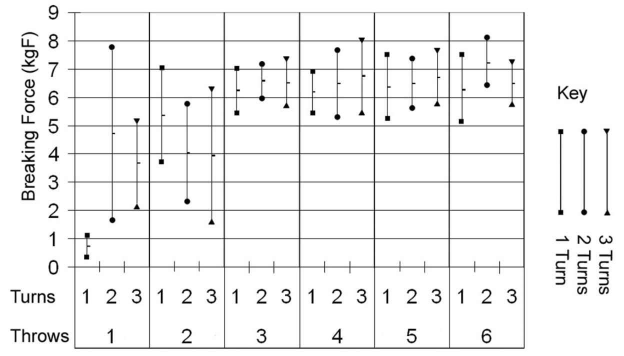

Figure 11 Mean and standard deviation for each configuration of Aberdeen knot.

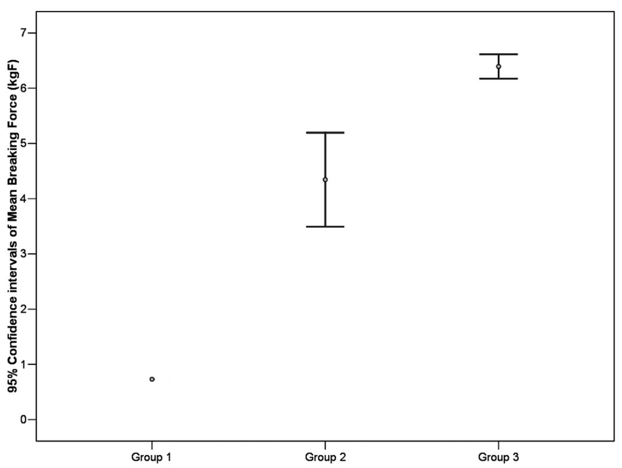

Figure 12 Mean breaking force for each group. Note, there is no error bar for Group 1, as it only contains a single data point.

The knots appear to fall into different groups as is particularly evident in Figure 11.

The first group comprises a single knot, the Aberdeen knot formed from one throw and one turn. In practice, this knot of low strength is only used for closing skin, where the forces on the knot are minimal. This knot has a small volume and is often not palpable under the skin.

The second group includes the knots from one throw and two turns up to two throws and three turns. This group has wide standard error bars indicating the variable performance of such knots. Sometimes they would hold and be tested until they broke and sometimes they slipped.

Group 3 contains the remainder of the knots and these have more than two throws.

Figure 12 and Table 2 summarise the differences among the three groups. The means of Groups 2 and 3 are significantly different (Mann-Whitney U-test, $P = 0.0016$). As there is only one data point for Group 1, it cannot be compared statistically with the other groups.

Figure 11 shows that there is not much difference between the mean breaking strengths of the knots with

Table 2 Properties of the three groups

Group	No of configurations	No of experiments	Contains	Mean breaking force (kgF)	SD of mean (kgF)	Minimum breaking force (kgF)	Maximum breaking force (kgF)
1	1	1	1 Throw 1 Turn	0.73	–	0.3	1.3
2	5	49	1 Throw 2 Turns to 2 Throws 3 Turns	4.34	0.69	0.4	7.9
3	12	120	3 Throws 1 Turn to 6 Throws 3 Turns	6.52	0.28	4.3	8.1

Table 3 Two-way ANOVA for Group 3

	DF	Sum of squares	Mean square	F	*P*-value
Throws	3	0.80	0.267	0.354	0.7864
Turns	2	4.115	2.057	2.729	0.0698
Residual	108	81.405	0.754		

more than two throws (Group 3). The result of adding turns is more difficult to deduce. Figure 13 shows the effect on the breaking force of knots with various numbers of throws. It would appear that a two-turn construct may be the strongest.

Further analysis of Group 3 with ANOVA to investigate whether the number of turns has an effect on the strength of the knot construct is illustrated in Table 3.

It can be seen from Table 3 that the number of throws has no significant effect upon the strength ($P = 0.79$), whereas the number of turns is more important ($P = 0.07$). This may represent a trade off between the strength of a knot with three or more turns and the difficulty of tightening it.

Conclusions

The Aberdeen knot is self-tightening. Unfortunately, as it tightens, the extra length induces slack in the suture line. It is, therefore, imperative to tighten the knot initially. The ideal Aberdeen knot would be the one with the least number of throws and turns, which would always lock and not slip, whilst also being easy to tighten.

In this study, the Aberdeen knot was seen to behave in two different ways under increasing tension. Either the throws and turns unfolded themselves, and the knot slipped, or the knot held and the suture broke in or near the knot.

Increasingly complex knot constructs with fewer than three throws (Group 2), exhibited increasing strength. No benefit accrued from employing more than three throws. It appears that the strongest knot of all has three throws and two turns.

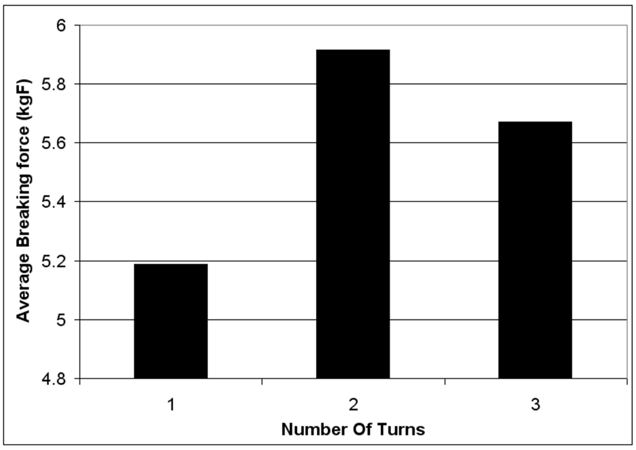

Figure 13 Average breaking force for Aberdeen knots with number of turns specified.

The authors would, therefore, recommend three throws and two turns. This configuration of Aberdeen knot was tested to destruction a further 145 times on the same machine. It did not slip once!

The Royal College of Surgeons of England has recommended six throws and one turn.[5] The results of the study reported above, do not support this recommendation.

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